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ABSTRACT

Controversies over the extent and duration of projected enrollment declines have made the techniques involved in such predictions a matter of interest in the field of educational planning. This document is a survey of current methodologies and problems in forecasting at the state and institutional level. Part 1 discusses: a review of methodology that describes forecasting methods such as ratio, cohort survival, Markov models, regression, optimization, combination methods, guess-estimation, and also national, state, and institution-level models. Part 2 deals with the problems and issues in enrollment forcasting. Part 3 discusses alternative future strategies and decisions. (Author/KE)

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Student Flow Modelling and Enrollment Forecasting

Controversies over the extent and duration of projected enrollment declines have made the techniques involved in such predictions a matter of interest to everyone involved in educational planning. This survey of current methodologies and problems in forecasting at the state and institutional level was written by Edward H. Lyell, director of planning and management systems, Colorado Commission on Higher Education, and Patrick Toole, associate professor of engineering design and economic evaluation, University of Colorado, Boulder. Their analysis may contribute to equipping a broader audience for discussions in this field.

Student flow modelling and enrollment forecasting is an activity familiar to nearly every higher education administrator, institutional researcher, and budget office staff member. The motivation, objectives, and methodology of these forecasts depend on the organizational or inter-organizational level involved, the time period under consideration and the technical ability of the researcher. Judging from the volume and frequency of forecasting activities, this is either a very futile or a very fertile area for further investigation.

Recent examples show that if even good enrollment forecasting techniques exist, they have not been well-applied. At the institutional level, the expensive failure of year-round operations at the University of California proves the need for better forecasting and modelling (8). At the state and national level, enrollment figures were projected during the sixties with an attitude similar to that of stock market analysts during the twenties. After the "crash" of 1969-70, however, projections became more realistic.

Despite an abundance of activity and recent advances, the state of the art at both the theoretical and applied level requires further development. Careful planning (therefore requires accurate forecasting) will be required if projected enrollment decreases are not to cause serious disruption in the higher education community.

I. A REVIEW OF METHODOLOGY

Any scheme for categorizing forecasting methods necessarily oversimplifies the state of the art. Nevertheless, it is convenient to classify techniques according to key parameters.

1. **Ratio Methods.** In one of the simplest techniques, an externally forecasted base population figure is multiplied by an estimated ratio to produce a projection a future time period. For example, the 18-21 age group multiplied by an estimated participation rate yields an undergraduate enrollment figure. The ratio technique is used primarily for aggregate figures at the state and national levels. Its advantages are simplicity of computation, ease of explanation to policy makers, and minimal data requirements. However, factors causing the ratio to vary may be overlooked in the analysis, causing an inaccurate forecast.

2. **Cohort Survival Methods.** The number of individuals in a given group or cohort is estimated for some time in the future by multiplying a fraction representing the survival rate times a base year number for the cohort. For example, the cohort could be the group of entering freshmen and the survival rate could be the number present as juniors six semesters later. Although the idea has considerable statistical validity, this technique has received very little attention in the literature. The lack of interest may be due to the neceessity to completely trace the transition history of each member of a given cohort of entering individuals; most institutions do not have this kind of data. Moreover, the method is useful only in predicting such aggregate figures as the number of juniors in year 1978.

3. **Markov Models.** These are also called linear fractional flow models. In statistics, a Markov process is one in which the future depends only upon the present and not on the past. During any given time period, students are classified in one of a fixed number of states. The fractional flow rates between states are then estimated (and are usually assumed to be time-invariant). Forecasting is initiated by multiplying these fractions by the inventory numbers in the states given by historical enrollment figures for the base year. After accumulating the resulting numbers and adding in new admissions, a new set of enrollment inventories is produced for the first year's projections. The process is then repeated for

the number of periods to be forecasted. The output inventories at any given stage serve as the input for the next stage.

One of the earliest applications of this technique is the **grade progression ratio** method. This technique is used to project the number of students in each of grades one to twelve. For example, the projected number in grade six at time 1974 is taken to be a fixed parameter times the projected number in grade five at time 1973. The Markov model has been investigated, both abroad and in the United States, for projecting student and faculty flows at the national, state and institutional levels. For student flow modelling, a typical project might estimate the fraction of sophomore english majors who transfer to become junior sociology majors.

This technique has a number of appealing characteristics. The model is conceptually simple. The flow parameters are easily estimated from current data. The number of states can be expanded to give the model the highly disaggregate form required by some unit costing procedures. Yet the method has several drawbacks. Validation studies of disaggregate model forms have shown considerable discrepancies between predicted figures and actual data. The method's iterative technique compounds errors, and the nature of the Markov calculations may mask important trends or characteristics in the historical base data.

4. Regression Methods. In this method, functional relationships (called the regression equations) are specified between exogeneous, external variables and enrollment variables. The parameters specifying the functional relationships are then estimated using historical data for the values of the exogeneous and enrollment variables If the functional relations are linear equations, the technique is called **linear regression**. Ratio methods are actually a simple form of linear regression.

Regression analysis is a powerful tool of statistics for which a considerable body of theory exists. It has been widely applied in the social sciences and has been used in enrollment forecasting to relate aggregate enrollment figures, such as state-level undergraduate enrollment, to such exogeneous variables as the size of the 18-24 age groups, disposable real family income, tuition rates, changes in the armed forces, student financial aid, unemployment rates and so forth. The technique transfers the enrollment forecasting problem to that of forecasting the exogeneous variables, often a far more difficult problem. Care must be taken in the design of the regression model and in the interpretation of the results, serious pitfalls await the statistically naive.

5. Optimization Methods. This general category includes all those techniques in which enrollment projections are expressed as functions of previous enrollment projections, exogeneous variables, and decision variables. Some objective such as total cost or the number of degrees awarded is then optimized over all choices of values for the decision variables. Optimization methodology is primarily used for policy evaluation, but does produce enrollment forecasts. The parameter estimation techniques vary according to the functional relationship types used.

6. Combination Methods. In arriving at enrollment forecasts, some combination of these five methods is usually applied. For example, high school senior class sizes may be forecasted using grade progression ratios. the numbers of new applicants may be derived from these figures and the 22-35 age group using a ratio method; the result may be added into Markov or cohort survival figures to produce total enrollment.

7. Guess-Estimation. To paraphrase one administrator:

> "To fill in the enrollment forecasts on the state budget forms in the Fall, I gather together all the computer forecasts my staff has drawn up, I look at the data for several previous years, I look at the data that has just come in, I make a few phone calls, and I decide on the projections. I've never been off by more than one percent."

When it comes time to make a forecast that has to be lived with at the institutional level, model results must be tempered with insight and experience. Some of the above methods may look well on paper, but they are a waste of time and money unless they can provide an administrator with more accurate estimates than could be obtained intuitively.

National and State Level Models

Gani developed a Markov-type model in the early sixties to project total enrollment and the number of graduates for the university system in Australia (5). Two other Markov-type models have been developed at the national level, one in Britain (1) and one in Norway (20) Both have components which relate national manpower figures to enrollment projections. The British study traces the effects of bottlenecks, that is, not having enough positions for the number of qualified students applying for admission. National level studies in the United States are covered in the paper by Mangelson, et al. [article No 1 in this issue of *Planning*].

Until fairly recently, most states used simple ratio methods and grade progression techniques to forecast enrollment (15) is a typical case. More sophisticated methods have recently been proposed or adopted in many states Heading the list are the Markov-type of modelling procedures the Higher Education Enrollment Projection Method developed in the State of Washington is an example (21). The state classifications within the model are one for each of the community colleges, and one for each of the four undergraduate levels at the baccalaureate institutions. Ratio methods compute first

time enrollment figures. Linear fractional flow rates are used to calculate transitions between institutions and between states within an institution

A similar technique to project student numbers by institution and by student level was employed in Nebraska (19) That study claimed a validation figure of less than 7% for institutional enrollment after one year A linear fractional technique was used in Colorado to trace the flow of first time freshmen from geographical areas to institutions within the state (6). First-time freshmen numbers were predicted by performing a linear regression using selected age groups as the exogeneous variables Unfortunately the first time freshmen figure after one year showed an overall error of nearly 20% when compared with actual data.

A study in Michigan incorporated a linear regression technique to forecast undergraduate and graduate enrollment by public four year, private, and community college institutional types (14). The exogeneous variables were high school enrollments, populations in selected age groups, real per capita income, total real personal income, employment rate, and discharges from the armed services Three different sets of projections were made corresponding to three different sets of assumptions concerning the level of student access. Unfortunately, the model predicted an increase in enrollment in the first year after the base year, actually there was a significant decrease A very recent study in New York projects the state's full-time undergraduate enrollment through 1990 using such traditional techniques as ratio methods (7) The result of the calculations is that institutions not in the high demand group (those which accept a relatively low percentage of applications received) will probably suffer severe undergraduate enrollment declines beginning in 1980

Institutional Models

The general trend in institutional models has been to develop a resource allocation model which utilizes an enrollment projection technique In one such example, the study of Koeing, et al, the enrollment sector forecasts student numbers by class level and major (10) Projections depend on student transition rates as well as available student financial aids.

The student flow model of NCHEMS (11) and the student flow sector of the CAMPUS model (9) are further examples of linear fractional flow techniques which classify students by level and major and are used in unit costing and resource prediction studies. Both models have received considerable exposure and can be used at the state as well as at the institutional levels (13).

The modelling study by Marshal and Oliver is based on the concept of "constant work," referring to the number of semesters required to graduate Cohorts of entering freshmen in 1955 and in 1960 were carefully analyzed (12) The fraction in attendance after any given number of semesters was almost identical for the two cohorts An enrollment forecasting scheme, keyed on this result, provided very accurate forecasts for lower and upper division figures (18). This idea has been extended at the University of Wisconsin to provide a technique for estimating individual course enrollments (2) Finally, a model by Oliver, Hopkins, and Armacost is of the optimization type (17). It represents a campus in equilibrium with respect to student flow behavior. Drop-out behavior is accounted for explicitly. Optimizing an appropriate cost from over all decision variables, constrained by the resulting set of equations, yields a number of interesting policy-level results such as the marginal cost of a degree, or the effect on total operating cost of the Carnegie Commission recommendations for a three year bachelor's program.

II. PROBLEMS AND ISSUES IN ENROLLMENT FORECASTING

The largest class of enrollment forecasting problems relate to the quality and types of available data needed. Historical cohort transition data, crucial to projecting students into academic programs and the most sensitive number for unit cost analysis, is frequently unavailable. Existing historical files are frequently inaccessible or are not directly usable for computer processing

Unresolved definitions often prevent comparability between institutions and, in particular, between states, in trying to trace interstate student flows and in-and-out migration patterns. There are problems in defining the difference between an on and off-campus student, a student by academic program, the difference between academic and vocational enrollment, and the change of students between programs. The identification of all postsecondary programs and the modeling and accounting of student flows between private proprietary schools and public institutions is an unresolved issue. The problem may be exacerbated by the reluctance of proprietary institutions, in a competitive market place, to make necessary information available to public officials.

Accounting for the uncertainties which arise from the impact of external variables upon student behavior poses another forecasting problem The effect of changing lifestyles, the end of the draft, the condition of the economy and its effects on student behavior, all may have a significant impact on the students' decision to attend school and to enroll in a specific program.

Consideration by the United States Congress about financing postsecondary education will have a somewhat predictable impact upon student enrollment, but remains an unknown and uncontrollable factor for state personnel State and federal legislative decisions are often external variables for institutions trying to determine enrollments in the coming year; they certainly are uncontrollable by the department chairman trying to plan class assignments. Understanding the exogeneous variables may be a clue to explaining the differences in enrollment forecasting results and the large errors in some recent forecasts. Perhaps the state of the economy is now the crucial variable

Validating a proposed methodology is another major issue. In the few instances of careful comparison between actual and forecasted enrollment, very large discrepancies have been revealed. Colorado's enrollment has gone up close to 15%, especially in the community college sector, whereas a prediction was made for either little gain or a slight loss at each institution. The reasons for this change have not yet been determined, although analysts suspect it was due to such exogenous variables as economic conditions and the employment rate. Very simplistic methods and estimates will continue to be employed until policy makers are convinced that more sophisticated procedures give accurate, validated results.

III. ALTERNATIVE FUTURE STRATEGIES AND DECISIONS

The validation and evaluation of existing attempts at forecasting student enrollment and estimating the student flow through academic programs must become an ongoing activity at each institution and agency. Rather than having independent forecasts at each institution and separate forecasting methodologies used by the state, a consensus should be reached among concerned parties for a procedure to be used at each institution such that information can be aggregated for use by the state The dialogue must be continuous between parties and related to other state and national efforts, such as NCHEMS at WICHE.

The authors suggest that identification of exogenous variables and the causal effect of these variables upon enrollment forecasting and student flow is probably the most important research area. This includes evolving social patterns, attitudes, and in particular, economic studies unemployment, disposable income, and public expectations of achieving expanded economic opportunities through higher education. The ability to predict enrollment is quite dependent upon the ability to predict the causal effect of exogenous variables. In the past procedures tended to begin with a look-to-the-past to predict the future, based on the assumption that the past is in some way congruent with the future. In a time of inflation, unemployment and a severe increase in the rate of societal change, it is even more important to examine the total impact of events upon student numbers.

Attention should be given to more innovative methods and to techniques that can be validated. Models must be based on parameters and trends that can be estimated accurately The model building and data validation processes must be simultaneous activities. Finally administrators must be involved in the discussion of forecasting methodologies they must understand the model, develop confidence in forecasted results, and be able to use the input in their decision-making process.

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